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ABSTRACT

This study investigated the effects of solution-oriented and strategy-oriented feedback when using interactive computer-assisted instruction. The feedback confirmed problem solving strategies that were either similar to the learner's cognitive strategies (i.e., spatial strategies) or different from the learner's cognitive strategies (i.e., perceptual strategies). A pretest consisting of 32 three-term series problems was administered to the 65 undergraduates who served as subjects. They were then given four instructional guided discovery programs with identical instructions on the features of the problems and the relationships between the features. However, two of the programs gave instructions for spatial strategies to solve the problems, while the other two gave instructions for perceptual strategies to solve the problems. Posttests measured the effects of the instructional programs, and it was found that when the learners were instructed on the spatial strategies, strategy feedback was more effective than solution feedback. This suggests that feedback given throughout the instruction on problem solving modifies the learner's cognitive strategies only if the strategies in the instruction are similar--to some extent--to the learner's cognitive strategies. It was also found that strategy feedback was less effective in learning perceptual strategies than in learning spatial strategies, and less effective than solution feedback in learning the perceptual strategies. The text is supplemented by two figures and two tables. (28 references) (Author/EW)

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The Effect of Computer Based Feedback on Using Cognitive Strategies of Problem Solving

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ABSTRACT

The purpose of the study was to investigate the effects of solution oriented and strategy oriented feedback. The feedback confirmed problem solving strategies that were either similar to the learner's cognitive strategies i.e., spatial strategies, or different from the learner's cognitive strategies i.e., perceptual strategies. The dependent variables were: 1) the number of problems the learner solved correctly within a limited time, and 2) the number of learners who shifted to better choices on a questionnaire designed to measure their cognitive strategies. The subjects were 65 undergraduate students. Four computer programs were designed to instruct the subjects on spatial or perceptual strategies to solve three-term series problems, using strategy or solution feedback. The method of instruction was guided discovery. Significant interaction was found. The results partly supported a theoretical framework. Several questions were raised for future research.

The Effect of Computer Based Feedback on Using Cognitive Strategies of Problem Solving

In interactive computer assisted instruction, feedback may assist the learner to discover effective cognitive strategies of problem solving. Computer based feedback may present only the amount and type of information that assists the learner in identifying the relevant cues and relationships in a problem, and in selecting effective procedural rules for solving the problem. It may also enhance the development and use of cognitive skills that guide the learner in selecting and organizing effective rules to regulate and monitor deductions made toward the solution of the problem (Gagne, 1985; Gagne & Briggs, 1979; Gallini, 1985; Kozma, 1986; Tennyson, 1986).

Nevertheless, the effect of computer based feedback on the learner's development and use of effective cognitive strategies of problem solving has not been directly explored. Exploring this effect could guide the design and development of effective instruction in problem solving. It could, moreover, explain the contradictory results of the effect of feedback on learning.

Rigney (1978) identified four basic categories of techniques in automated instructional systems that may enhance the development and organization of the learner's cognitive processes. They are: 1) orienting tasks or directions that induce the learner, either directly or indirectly, to perform specific operations, 2) content bridges or material that is specific to a particular subject matter, 3) cognitive strategies that facilitate the acquisition, retention, and retrieval of subject matter, and that are initiated by the learner or the instructional system, and 4) knowledge of results. Rigney, however, did not specify how knowledge of results acts by itself, or how it interacts with the other elements in the system, to facilitate learning.

On the other hand, Kulhavy (1977) reviewed the literature on feedback used in written instructional material searching for an explanation of the contradictory findings of feedback research. He concluded that feedback following a correct response would be effective as it confirms the learner's "comprehension strategies" i.e., it informs the learner that his/her strategies helped achieve the goal. Feedback will be even more effective after an incorrect response as it allows the learner to identify the error, and under appropriate conditions, correct that error.

Research evidence suggested to Kulhavy that feedback is ineffective in two instances. The first is when the learner is unable to comprehend the instruction and fit it in an existing cognitive framework. In this instance the learner keeps guessing at the answer and trying to arbitrarily associate a

response with a correct answer. The second instance is when the feedback is available to the learner before he/she responds, an instance that is avoidable in computer assisted instruction.

In line with the conclusions Kulhavy drew from the feedback research, Rumelhart & Norman (1978) stated that feedback may affect the learner's cognitive operations in one of three ways. It may: (1) confirm a correct answer and thus lead to the addition of new information to existing schemata and strategies, (2) tune the existing schemata and strategies by pointing to minor errors that need correction, or (3) point to major errors in the learner's schemata and strategies, and guide the learner in restructuring them, which is a difficult and time consuming task.

The above theory works on the assumption that feedback confirms definite cognitive frameworks and strategies. However, in computer assisted problem solving there are cases when feedback is designed to confirm correct solutions to problems regardless of the cognitive strategies the learner follows to arrive to the solutions. The learner could arrive to the same solutions using different cognitive strategies, or no clear strategies.

Consequently, feedback in problem solving instruction may be: 1) solution oriented, as when it informs the learner whether the product of a mathematical problem—for example—is correct or incorrect regardless of the procedures and cognitive strategies used to arrive to the product, and 2) strategy oriented, as when it informs the learner whether the cues and relationships he/she identifies in a problem are relevant and correct, whether the rules he/she follows are appropriate, and whether his/her way of organizing and applying the rules is efficient.

Moreover, the effect of feedback may interact with the cognitive strategies the learner develops before the instruction. In other words, the effect of feedback does not only depend on whether the feedback is strategy oriented or solution oriented, but also on whether the learner is using certain cognitive strategies in the first place. Consequently, solution feedback may unintendedly and indirectly confirm or not confirm the cognitive strategies the learner is using. Figure.1 represents the predicted interaction between feedback and the learner cognitive strategies.

INSERT FIGURE 1 ABOUT HERE

Figure 1 shows that feedback may increase, decrease, or not affect performance in a problem solving situation. The effect of feedback depends on: 1) the function of feedback (strategy oriented or solution oriented), and 2) whether the feedback confirms or does not confirm the cognitive strategies the

learner is using.

Evidence from research suggests an interactive effect between feedback and the learner's possible use of cognitive strategies. Boysen, 1980; Isham, 1980; and Renzi, 1974 found that field-dependent subjects benefited from explanation feedback more than field-independent subjects. Since field-dependent subjects are inclined to respond to the environment in a global rather than an analytical way, they may also be less inclined to develop and use cognitive strategies in problematic situations. Field-dependent subjects are therefore expected to benefit more from feedback as it helps them identify relevant features and relationships in a problem, and helps them select or develop appropriate procedures and cognitive strategies.

Contrary to the above findings, Boysen & Thomas (1980) found that field-dependent subjects benefited more from "implicit feedback" while field-independent subjects benefited more from "explicit feedback". The subjects' task was to practice solving linear equations. Impilicit feedback showed subjects how to perform operations they requested regardless of whether these operations were relevant or irrelevant to the problem at hand. Explicit feedback showed subjects how to perform the operations they requested only when the operations were relevant to the problem. If the operations requested were irrelevant, the subjects were shown the relevant operations.

As the experimenters noted, a field-dependent subject could have benefited from the analytical operations provided by the impilicit feedback. On the other hand, field -independent subjects could have been testing strategies through explicit feedback. Had explicit feedback been given to field- dependent subjects through force order instruction, they probably would have performed better receiving explicit rather than implicit feedback.

Cognitive strategies could be an intermediate variable responsible for the unexpected results of feedback found by Spock (1987). The performance of undergraduate students instructed in BASIC did not vary when they received explanatory feedback from the performance of others who received knowledge of results feedback. However, the results did indicate that subjects with prior knowledge benefited more from explanatory feedback. Since prior knowledge is an indicator of the availability of cognitive frameworks and strategies (Larkin, McDermott, Simon, & Simon, 1980), those subjects may have been able to improve their frameworks and/or strategies as they received explanatory feedback.

Johnson & Plake (1977) found that graduate students performed better when they received feedback after each step they made in the analysis of variance. Similarly, Roper (1977) found that the performance of undergraduate students in statistics was superior when they received feedback that stated

the correct answer compared to their performance when they received feedback that simply indicated whether their response was correct or incorrect.

The purpose of the present study was to investigate the effect of strategy feedback and solution feedback on developing and using cognitive strategies of problem solving. The effect of this variable was studied as it interacted with the learner's cognitive strategies.

Strategy feedback was given to the subjects throughout instruction on problem solving. The feedback informed them whether their responses to the features of a problem, the relationships between the features, and the procedures they followed to solve the problem were correct or incorrect. The feedback also indicated what the correct responses were, and why. Solution feedback was given to the subjects only as they solved practice problems to inform them whether a solution to a problem was correct or incorrect, and what the correct solution was.

Strategy feedback and solution feedback either confirmed or did not confirm the subject's cognitive strategies. This was done by measuring the cognitive strategies the subjects used to solve problems prior to the instruction, then instructing them on strategies that were either similar to, or different from the cognitive strategies they used.

Two dependent variables were used. They were: 1) the number of problems solved correctly within a limited time on a posttest, and 2) the number of the subjects who shifted to a better choice on a questionnaire designed to measure the strategies they used to solve pretest and posttest problems.

The following hypotheses were tested:

1. The performance of the subjects who receive strategy feedback that confirms their strategies will be superior to the performance of the subjects who receive solution feedback that indirectly confirms their strategies.
2. The performance of the subjects who receive strategy feedback that confirms their strategies will be superior to the performance of the subjects who receive strategy feedback that does not confirm their strategies.
3. The performance of the subjects who receive solution feedback will be superior to the performance of the subjects who receive strategy feedback that does not confirm their strategies.
4. The performance of the subjects who receive solution feedback that indirectly confirms their strategies will be superior to the performance of the subjects who receive solution feedback that does not confirm their strategies.
5. More subjects will modify their cognitive strategies when they receive strategy feedback than when they receive solution feedback.

METHOD

Subjects:

The subjects were 65 volunteer udergraduate students, males and females, enrolled in three sections of a computer literacy class at the University of Texas at Austin. The subjects were assigned randomly to four groups, corresponding to the four cells of a 2*2 factorial design.

Pilot Study:

A pilot study was conducted on 32 students drawn from a fourth section of the same computer literacy class. The main purpose of the pilot study was to determine whether the students used cognitive strategies to solve the type of problems used in the study, and if they did, what kind of strategies. The materials and measurments developed for the main study were used in the pilot study. The results of the pilot study indicated that 30 out of the 32 students used spatial cognitive strategies to solve the problems. A ceiling effect was also detected. Appropriate changes were thus made in the materials and procedures.

Materials:

Instructional Content: Instructional content was selected to be generic problem solving. Three-term series problems were used. An example of the problems is:

Sandy is taller than Wanda.
Wanda is taller than Albert.
Who is the tallest?

There are 8 different determinate structures to this problem. For each of these structures, two problems may be formulated: (1) one problem when the final question asks for the largest term, and (2) the second problem when the final question asks for the smallest term. Consequently, a total of 16 problems could be constructed using the same terms and comparatives. Countless problems, however, could be constructed using different terms and comparatives.

In the present study, the names of males and females were used as terms. Different verbs and comparatives were also used to avoid the repetition of the problems, and to relate them to events familiar to the subjects.

Since three-term series problems are logical problems, valid inferences are drawn from their premises. A rule of inference is essentially syntactic in nature i.e., it dictates what can be drawn from expressions on the bases of their forms regardless of their meaning (Johnson -Laird, 1985). Evidence from research indicates that college students solved three-term series problems using spatial cognitive strategies (De Soto, London, and Handle, 1965; Huttenlocher, 1968). In addition,

some students discovered the perceptual features of the problem and developed perceptual strategies to solve them. (Johnson-Laird & Bara, 1984; Quinton & Follows, 1975). The perceptual strategies enabled the subjects to solve the problems without forming the series, and with a minimal load to the working memory. As a result, the subjects who used perceptual strategies took significantly less time to solve the problems than those who used spatial strategies.

In the present study, four computer programs were developed. The four programs gave identical instruction on the features of the problems and the relationships between the features. Two out of the four programs gave instruction on spatial strategies to solve the problems, while the other two programs gave instruction on perceptual strategies to solve the same problems. The instruction on the strategies was followed with identical practice problems.

The method of instruction in the four programs was the guided discovery method, as outlined by Collins (1985). Forty two questions were posed systematically in each program to guide the learner to relevant aspects of the problem, and to the thinking skills needed to solve the problems when following either spatial or perceptual strategies.

One spatial strategies program and one perceptual strategies program gave strategy oriented feedback, while the other two programs gave solution oriented feedback. The strategy feedback indicated to the subjects, after each response to the forty two questions in the program, whether the response was correct or incorrect. If the response was correct the subjects were still informed of the correct answer, and of why the answer was considered correct. If the response was incorrect, the cues relevant to the answer were highighted for the subjects and they were asked to try again. The subjects were informed after the second try if the response was correct or incorrect, informed of the correct answer, and of why the answer was considered correct.

The solution feedback was given to the subjects after solving the practice problems only. The subjects were informed whether their solution was correct or incorrect and were asked to try again. The subjects were then informed whether their second try was correct or incorrect, and of the correct solution.

Measurment Of Problem Solving: Sixty four three-term series problems were designed after the 16 possible determinant problem structures, four for each structure. Thirty two of these problems were used as a pretest and the other 32 as a posttest. The pretest and the posttest problems were matched.

Measurement Of Cognitive Strategies: A questionnaire was developed to measure the cognitive strategies the subjects used to solve both the pretest and the posttest problems. The questionnaire consisted of 20 multiple choice items and one

short answer item. Eight of the multiple choice items were about the features of the problems and the relationships between the features. Six items were about the spatial strategies, and the remaining 6 items were about the perceptual strategies. There was a better answer to each item. The better answer reflected the most efficient way to solve the problems. The short answer item asked the subjects to list mental tricks, strategies, rules, or steps they followed in their mind as they solved the problems.

Procedure:

The experiment was conducted in two sessions. During the first session, each subject in a section of the computer literacy class was instructed to solve the 32 problems of the pretest as quickly and accurately as possible, without using any materials such as paper and pencil, and without using his/her hands or fingers to figure the solution. The instructions informed the subject that he/she would have 7 minutes to solve the problems, and that the computer would stop presenting the items when the time was up.

At the end of the test, the subjects were shown the number of correct responses, and were asked to answer the questionnaire. The computer recorded the subjects' correct responses on the pretest.

During the second session, a week later, the subjects followed similar procedures, only this time they went through one of the four instructional programs before the posttest. In addition, the programs cued the subjects to enter the time they started the instruction and the time they finished it.The computer recorded the subjects' correct responses during the instruction and during the posttest.

The tests and instruction were administered via an Apple 11E computer. They were written using Super Pilot.

Design:

A 2 * 2 between subjects factorial design was employed, the factors being: 1) feedback, strategy oriented or solution oriented; and 2) the cognitive strategies the feedback confirmed, spatial strategies or perceptual strategies. The spatial strategies were similar to the subjects' cognitive strategies, while the perceptual strategies were different from the subjects cognitive strategies.

RESULTS

Table 1 shows the means and standard deviations of the 4 treatment groups for the pretest and the posttest scores, the time spent in receiving the instruction (in minutes), and the number of correct responses during the instruction.

INSERT TABLE 1 ABOUT HERE

The means were higher in the posttest than the pretest, while the standard deviations were lower. The median of the entire sample on the pretest was 29.00 out of a possible score of 32, and the range was 19. The median was raised to a score of 31 in the posttest, with a range of 14.

Pearson correlation coefficients were calculated between pretest scores, posttest scores, treatment duration, and number of correct responses during the treatment. Significant positive correlations were found between posttest scores and pretest scores (coefficient = .52, n = 65, p = .000), and between posttest scores and number of correct responses during treatment (coefficient = .30, n = 64, p<.01). A significant positive correlation was also found between treatment duration and number of correct responses during treatment, (coefficient = .40, n = 57, p = .001).

Spearman-Brown test of reliability was conducted on the 6 items of the questionnaire that measured Ss cognitive spatial strategies, and on the 6 items that measured their cognitive perceptual strategies using the split half method. The reliability coefficients were .89 and .66, respectively.

Prior to performing ANCOVA, the assumption of homogeniety of regression was tested for the posttest as a dependent variable and the pretest as a covariate. The test was nonsignificant (p>.32), indicating that homogeniety of regression was tenable. Table 2 reports the results of ANCOVA.

INSERT TABLE 2 ABOUT HERE

Table 2 shows that the main effects of both factors were nonsignificant. However, there was a significant feedback by strategy interaction $F(1,60) = 4.22$, p = .04. The interaction is illustrated in Figure 2.

INSERT FIGURE 2 ABOUT HERE

Figure 2 shows that strategy feedback was more effective when it confirmed strategies that were similar to the subjects' cognitive strategies i.e., spatial strategies, than when it confirmed strategies that were different from the subjects' cognitive strategies i.e., perceptual strategies. The adjusted means were 30.52 and 28.59, respectively. Conversely, solution feedback was more effective when it confirmed the perceptual strategies (adjusted mean = 30.16) rather than the spatial strategies (adjusted mean = 29.37).

Chi squares were conducted on each item of the questionnaire to find out the effect of the four treatments on the number of subjects who shifted to a better choice. Significant differences were found with respect to 4 items only. Chi squares were then conducted to investigate the effect of strategy feedback versus solution feedback on the number of subjects who indicated that they changed the strategies they used after the instruction from those they used prior to the instruction. The Chi square was significant (Chi square = 3.90, df = 1, p = .05)

DISCUSSION

The purpose of the study was to examine the effects of solution oriented and strategy oriented feedback. The feedback confirmed problem solving strategies that were either similar to the learner's cognitive strategies (spatial strategies), or different from the learner's cognitive strategies (perceptual strategies). The dependent variables were: 1) the number of problems the learners solved correctly within a limited time, and 2) the number of learners who shifted to better choices on a questionnaire designed to measure their cognitive strategies.

When the learners were instructed on the spatial strategies, strategy feedback was more effective than solution feedback. The results suggest that feedback given throughout the instructon on problem solving modifies the learner's cognitive strategies only if these strategies are similar—to some extent—to the learner's cognitive strategies. These results support the notion of a corrective (Kulhavy, 1977), or tuning (Runelhart & Norman, 1978) effect of feedback on cognitive frameworks and strategies. The results are also consistant with the findings of Johnson & Plake, 1977; Roper, 1977; & Spock, 1987.

On the other hand, strategy feedback was less effective in learning perceptual strategies than in learning spatial strategies. Moreover, strategy feedback was less effective than

solution feedback in learning the perceptual strategies. That 'more' feedback may have no effect (Kulhavy, 1977), or an adverse effect (Rumelhart & Norman, 1978) when the instruction tries to develop different or difficult frameworks and/or strategies is also supported by research evidence (Gilman, 1969; Merrill, 1985; Schoen, 1972; Spock, 1967; & Steinberg, 1980).

Comparing the results of the interaction detected in the study with the predicted interaction illustrated in figure 1, we find that the predicted effects of strategy feedback are confirmed. That solution feedback would be less effective than strategy feedback when the learner is instructed in strategies that are similar to his/her own cognitive strategies is also confirmed. The unpredicted results, however, are the positive effect of solution feedback on learning strategies that are different from the learner's cognitive strategies.

It may be noted that the instructional method used in the study was the guided discovery method. The entire information given to the subjects was in the form of questions. The subjects were to find the answers to those questions by observing examples of the problems. The process of guiding the learner into discovering features, relationships, and rules; and of organizing the rules to efficiently solve the problems, was gradual. It is plausible that providing feedback during the process of discovering the new perceptual strategies was interrupting to the flow needed for this process. Solution feedback during practice may have confirmed the strategies the learners were able to discover on their own during equistion. Merrill (1985) cited evidence for the effectiveness of questions on discovery learning, and for the ineffectiveness of feedback during the discovery process. More research is needed to compare the effect of feedback during the processes of strategy acquistion and practice.

It is speculated that the ineffectiveness of strategy feedback in learning strategies that are different from the learner's cognitive strategies may be apparent only during the preliminary stages of learning. However, as the learner starts to reconstruct his/her cognitive strategies and starts testing them, feedback may assume its corrective function. In the present study, more learners indicated a change in the cognitive strategies they used to solve the posttest problems. Research is needed to compare the effect of strategy feedback, and solution feedback at different stages of an extended instruction. Similar research is also needed to compare feedback effects on learners with low and high problem solving skills, on learners with clear cut and unclear cognitive strategies, and on learners who are confident or are not confident in the efficiency of their cognitive strategies.

It is of interest to note that the two major types of strategies used to solve three term-series problems—spatial and perceptual—were reported in studies using different problem solving tasks (Greeno, 1976; Larkin et al., 1980; Wood & Shotter, 1973). Reseach is needed to find out if the effect of training in one type of strategies or the other transferes to different problem solving tasks.

Since problem solving strategies are learnable, and since the cognitive strategies the learner develops may not be efficient, more computer assisted instruction is needed in this area. Instruction on strategies of problem solving would be based on measures of the learner's cognitive strategies. A choice of strategy feedback or solution feedback would depend on the efficiency of the learner's cognitive strategies, and on whether the strategies to be learned are similar to, or different from the learner's cognitive strategies.

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Table 1.
Means and Standard Deviations of the Four Treatment Groups

Treatment	Pretest	Posttest	Time	Correct During Instruction
Solution Feedback, Spatial Strategies (n = 13)	27.60 (3.67)	29.92 (2.94)	14.46 (3.39)	34.54 (3.10)
Solution Feedback, Perceptual Strategies (n = 16)	24.56 (5.59)	29.81 (2.43)	14.43 (3.52)	33.81 (4.64)
Strategy Feedback, Spatial Strategies (n = 17)	26.18 (4.95)	30.65 (1.19)	18.57 (2.58)	37.81 (1.84)
Strategy Feedback, Perceptual Strategies (n = 19)	24.63 (5.96)	28.26 (4.43)	22.53 (3.91)	36.42 (2.74)
Total Mean (n = 65) Standard Deviation	25.62 (5.39)	29.60 (3.13)	17.40 (5.13)	35.73 (3.61)

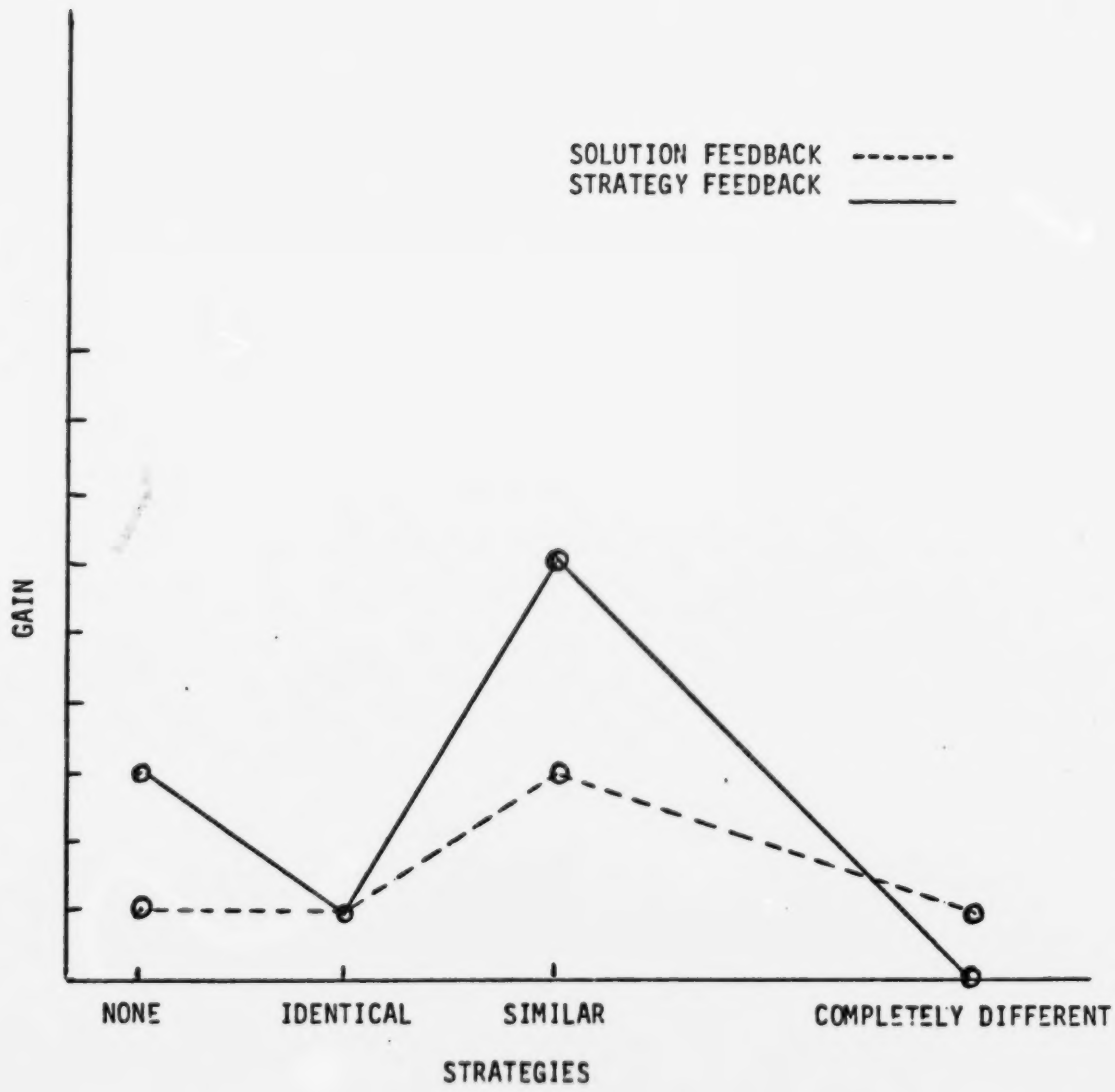
Note: Maximum score = 32 for each test, 42 for instruction.

Table 2.
Anaysis of Covariance for Posttest

Source	SS	df	MS	F	Sig. Level
Within Cells	417.32	60	6.96		
Covariate	155.61	1	155.61	22.37	.000
Feedback	.70	1	.70	.10	.75
Strategies	4.85	1	4.85	.70	.41
Feedback*Strategies	29.36	1	29.36	4.22	.04

Figure Captions

Figure 1. Predicted Interaction Between Feedback and the Learner's Cognitive Strategies.
Figure 2. The Interaction Between Feedback and the Strategies it Confirmed.


SOLUTION FEEDBACK
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GAIN
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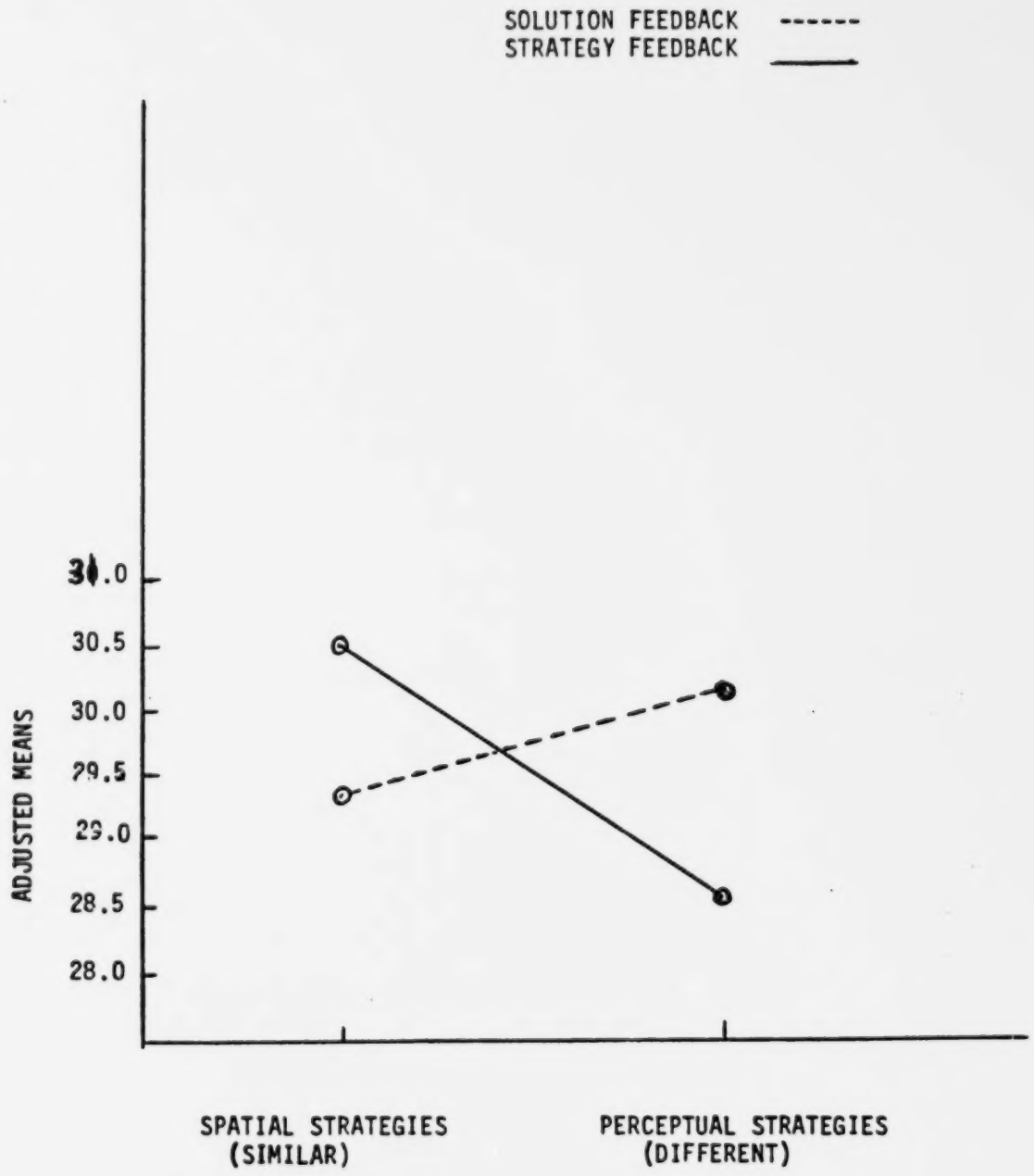
Fig 2


SOLUTION FEEDBACK
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SPATIAL STRATEGIES
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